Eolian contribution to the sediment budget the Coast of Ebro Delta

Análisis de la Contribución Eólica en el balance sedimentario del litoral del delta del Ebro

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ABSTRACT

Eolian processes play an important role in the littoral sedimentary distribution on the coast of the Ebro delta (NW Mediterranean). The sand budget following transport along the coast has been quantified only by nearshore processes. The present contribution examines a recent pilot experiment in beach nourishment in Riumar zone (mouth zone) and its participation in the formation of coastal fringing and internal dunes. At the same time a survey of evolution of the sand dune field in the Fangar spit (NW part of Ebro delta) which measured changes in the cross-sectional area showed a negative balance in a few years related to river climatic changes and resulting from the decrease in river sediment input to the deltaic alongshore sediment transport system.

RESUMEN

Los procesos eólicos juegan un papel muy importante en la configuración global del delta del Ebro. Este artículo engloba los resultados de diferentes estudios realizados en esta área que muestran las diferentes morfologías dunares, sus características generales y su relación con los agentes dinámicos. En el estudio de la regeneración piloto llevada a cabo en la playa de Riumar se observó la generación y evolución de dunas migratorias. El seguimiento del campo de dunas del Fangar muestra un balance sedimentario negativo relacionado con los cambios del regimen fluvial y la disminución de los aportes que alimentan el transporte litoral.

Key words: *Ebro delta, alongshore sediment transport, coastal dune field, coastal dunes, regressive coast.*

Geogaceta, 20 (2) (1996), 434-437
ISSN: 0213683X

Antecedents

Coastal dunes of the Ebro delta have been studied by various authors. The first was Mallada (1889), who remarked coastal dunes between Fangar and Buda island. Duboul-Razavel (1958) drew a map of coastal dunes in Trabucador spit and Fangar. Serra (1971) studied the old coast dunes in Sant Antoni island. Maldonado (1972) studied the Ebro delta and its evolution and mapped the emerged forms and playing special attention to the coastal dune field in Fangar spit, coastal dunes from Marquesa to Riumar beach and in Sant Antoni island. We have another cartography of dunes in geological maps (Maldonado, 1980 and 1982). Riera (1991) studied the present river mouth, the nearshore and adjacent zones, and lower course of the river; she remarked coastal dunes in Sant Antoni island. The last one was Guillén (1992) who mapped the Fangar coastal dune field in 1983.

Introduction

Dune formation is a function of sediment grain size, the characteristics of the beach profiles, the wind regime, and sediment supply, which react to environmental change on a variety of time scales, especially to variations in sediment supply and the sea-level change. Dunes develop within a broad framework of environmental controls, including tectonics, sea-level change, sediment availability and beach and nearshore conditions. Locally, and over relatively short time scales (months, years, decades,...), sediment availability is the most important factor, followed by wind regime (Carter, 1985; Davis *et al.*, 1987 and Carter *et al.*, 1990).

In Ebro delta, river sediment input to the deltaic alongshore sediment transport system decreased after the construction of the Mequinensa-Ribaroja-Flix dam complex. These dams are located on the lower course of the river some 150 km from the mouth and have strongly influenced the present configuration of the delta. It is calculated that this complex (built in nineteen sixties and seventies) retains up to 95% of the river's sediment transport. At the beginning of this century 17-25* 10^6 Tm/y was carried, after construction of the dam complex the transport was 0.15 *10^6 Tm/y (Palanques *et al.*, 1990 and Guillen, 1992).

Wind distribution in the Ebro delta zone shows a broad directional spectrum. High-velocity winds occur from the NW and have long duration. These are associated with the eolian sediment transport and dune generation in this area.

In the littoral zone of the Ebro delta we can recognize different dune forms.

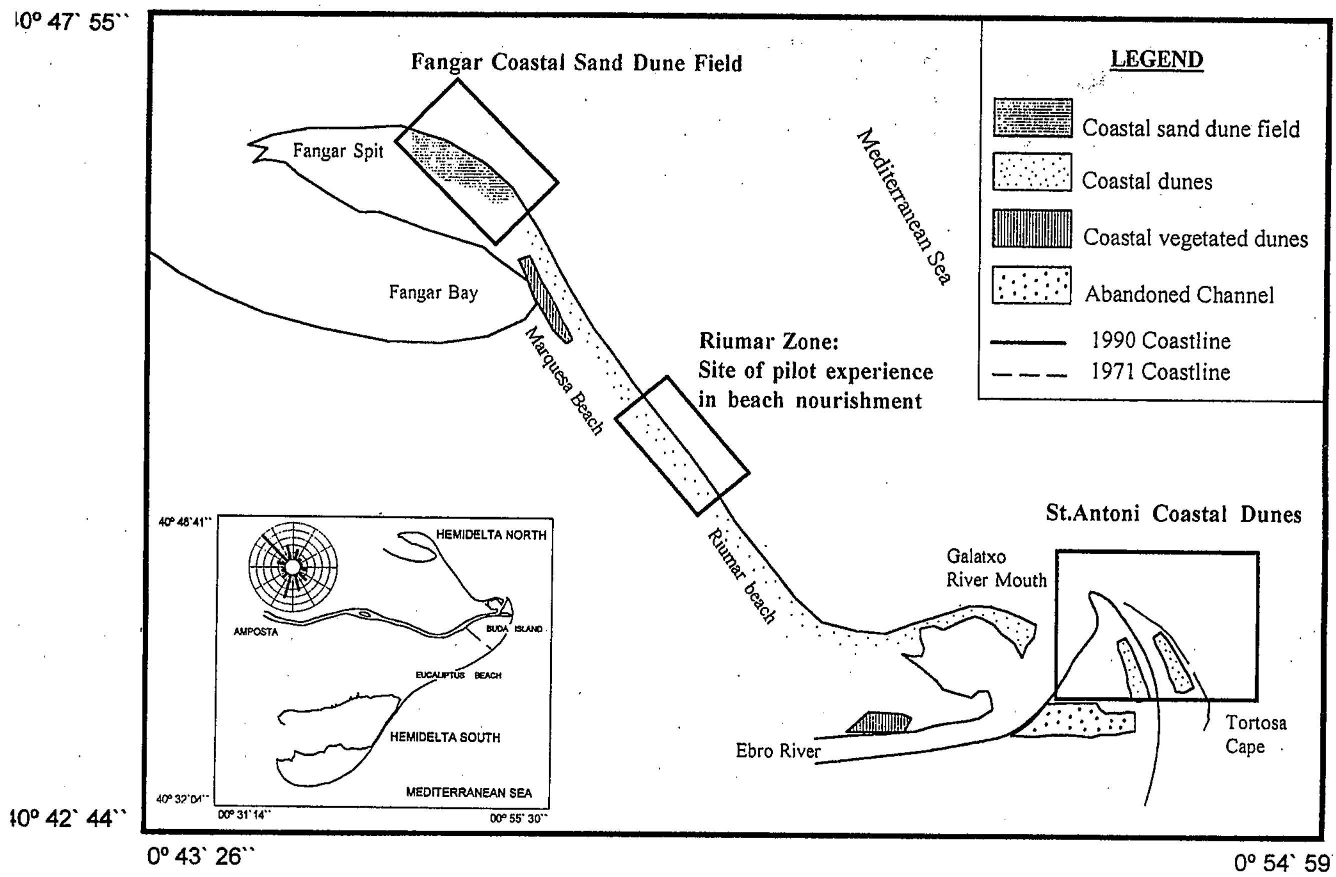

Fig. 1.- Map locating the study zones

Fig. 1.- Mapa de localización de las zonas estudiadas

The largest coastal dune fields are located in Fangar spit. Actually, in northern hemidelta we found coastal dunes in Marquesa to Riumar beach and Sant Antoni island and in southern hemidelta in Buda island and Eucaliptus beach. All these dunes, located in the southern hemidelta, are less important than dunes located in northern hemidelta. It is important to remark that there is an artificial coastal dune located in Trabucador spit. The difference in dunes in northern and southern hemideltas is related to the orientation of the coastline and the wind direction in each zone. This may explain why a big coastal dune field was found only in Fangar spit.

This paper reports three examples of coastal dunes in the northern hemidelta (Fig.1). The first is the coastal dune field in Fangar spit. We study its evolution by a survey of aerial photographs from 1957 to 1991. This information was completed with field data collected in 1993.

The second case-study includes the coastal dunes located in Marquesa to Riumar beach during a recent pilot experiment in beach nourishment in this zone and its participation in the generation and development of those coastal dunes. Field data were collected over a period comprised between August 1994 and January 1995.

The last example includes the coastal dunes of Sant Antoni island, observed in 1991 study of the river mouth, the nearshore and adjacent zones.

Results

Fangar coastal dune field:

The Fangar coastal dune field is the bigger in the Ebro delta. The distribution is seasonal, with strong influence of storms which reduce the coastal dune field extension. The extension of the dune field accumulating the sediment into sand sheets. Fair-weather conditions favour a renewed building of coastal dunes.

The evolution and evolution along time of this coastal dune field deduced from a series of aerial photographs from: 1957, November 1971, July 1983, 1984, May 1989 and April 1991 (Fig.2), and we have obtained these results (Table 1 and Fig.3)

The results of field data collected during July 1993 in Fangar spit, show the morphology of dunes and the value of crest height. Maximum crest height values is 3.3 m and the minimum is 1.25 m with a medium crest height of 2.1 m. Fixed dunes in this area present a medium crest height of 1.9 m which is the minimum crest height value of the dunes in the last few years. Observations at the end of the nineteen sixties show that maximum height value of these dunes were between 6 m and 8m (Serra, 1971).

The present data show an increase of 25% in the coastal dune field: in the period 1957-1983 the average area was 165000 m^2; on 1984-1991 the mean area was 225000 m^2. In 1991 the volume of this coastal dune field was 450000 m^3 but it is difficult to calculate the volume for

Time (year)	1957	1971	1983	1984	1989	1991
Area (m^2)	163000	175000	158500	239000	214000	228000

Table 1.- Variation of area Fangar coastal dune field.

Tabla 1.-Variación del campo de dunas del Fangar

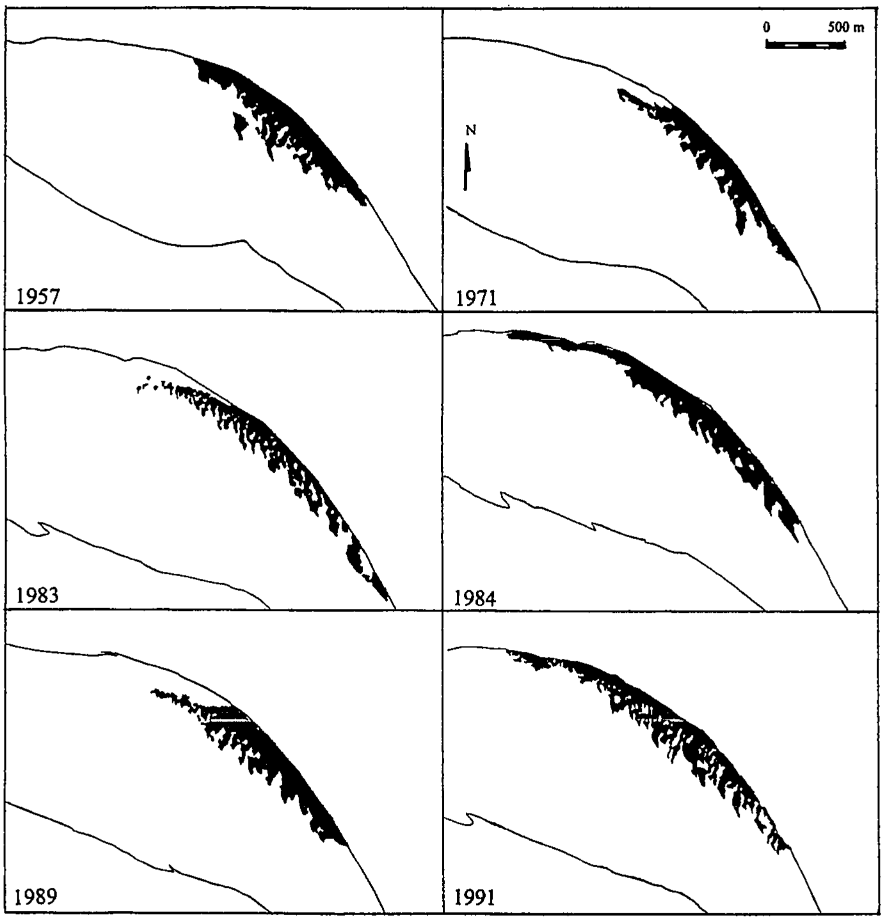

Fig. 2.- Evolution of Fangar coastal dune

Fig. 2.- Evolución del campo de dunas del Fangar

previous years because the mean crest height is unknown.

Surface variation of Fangar coastal dune field is a function of the distribution of dominant winds. When these are unimodal (for example NW winds) there is an increase in the area and a decrease in the mean crest height; the result is barkhan dunes. When the winds are polymodal, the extension of the coastal dune field is lower but the height is greater and dunes evolve into star type. The volumetric evolution of coastal dune shows a close relationship with the seasonal regime but morphological field data are also needed.

Coastal dunes in Marquesa to Riumar beach

In summer, 1994, the Generalitat de Catalunya carried out a pilot beach nourishment experiment in Riumar in an attempt to decrease the erosion of this area (Generalitat, 1995). The sediment was dredged from the Galatxo river mouth and the total volume, some 30000 m^3, was placed on the emerged beach. Favorable wind regime during this period contributed formation to the coastal dunes (Fig.3). Field data were collected between August 1994 (before dredging) and January 1995 (5 months after the end of the nourishment); the results show the migration of these coastal dunes.

For this study there were 7 fixed stations to measure the emerged profiles. The distribution was: 3 at the S where the sand was placed and 4 at the north of this point.

During this study we calculated a volume balance of the emerged beach profiles for each one and for the globalilty. The results are shown in Table 2:

Data obtained from total volume indicate erosion of about 8000 m^3. We can observe an increase in sediment volume of around 1100 and 1300 m^3 if we compare January 1995 - November 1994 and September - August 1994 campaigns. The last increase is due to the beach nourishment, and the increase observed during January 1995 and November 1994 may be partly due to the erosion of the sediment deposited on the beach and favorable conditions of wind and wave regime.

It is important to remark that when there is an input of sediment under favourable weather conditions, coastal dune formation and its migration are important on Riumar beach with a SE trend (Fig.3).

Profile	11/94-8/94	11/94-9/94	9/94-8/94	1/95-8/94	1/95-9/94	1/95-11/94
P1	-8	1	-9	-10.5	-1.5	-2
P2	2	2.5	-0.6	1	2	-0.5
P3	21	11	12	12	4	-5
P31	9	-51	61	-0.5	-56	-8
P4	-15	6	-20	-9	13	6.5
P5	-26	1	-28	-37	-10	-10.5
P6	-7	-15	9	3	-6	9.5
P7	-6	-6.5	0.4	-0.3	-1	6.5
S zone (P1-P31)	1980	-400	2650	-600	-2300	-1650
N zone (P31-P7)	-10100	-8500	-1500	-7400	-3270	2900
TOTAL	-8120	-8900	1150	-8000	-5570	1250

Table 2.- Volume balance of emerged profiles during the study period (in m^3/m for each profile and in m^3 for total balance)

Tabla 2.- Balance volumétrico de los perfiles emergidos durante el período de estudio (en m^3 / m por cada perfil y en m^3 para el balance total

Sant Antoni Island.

Sant Antoni island shows a high erosion rate with a 700 m displacement of the coastline in Tortosa Cape if we compare 1971 and 1990 maps (Fig.1). In 1971 there were 2 coastal dune systems parallel to the coastline, but one of these was eroded (in 1990 there was only the inner system of dunes).

In 1991, we studied the present river mouth, the nearshore and adjacent zones and we remark a coastal dune system between the emerged spit in the present river mouth to Tortosa Cape.

Medium crest height observed during February cruises was around 1 and 1.5. m. In November 1991 it has increased to 1.5 and 2 m.These differences were related to the changes in river mouth and to the climatic weather. Interaction of these 2 factors is very important but more surveys are required to study the evolution of this zone and quantify the sedimentary budget.

Final remarks

The evolution of eolian sand bodies and dune fields in a regressive deltaic environment, like Ebro delta, can be a good indicator of the degree of regressive trend. Sediment budget and climatic parameters are the controlling factors, as we have seen in the beach nourishment experiment in Riumar beach, and in the other two sectors described. A new two-years long project in Ebro delta attempt to elucidate and quantify the relation between climatic factors, sediment budget and coastal regression.

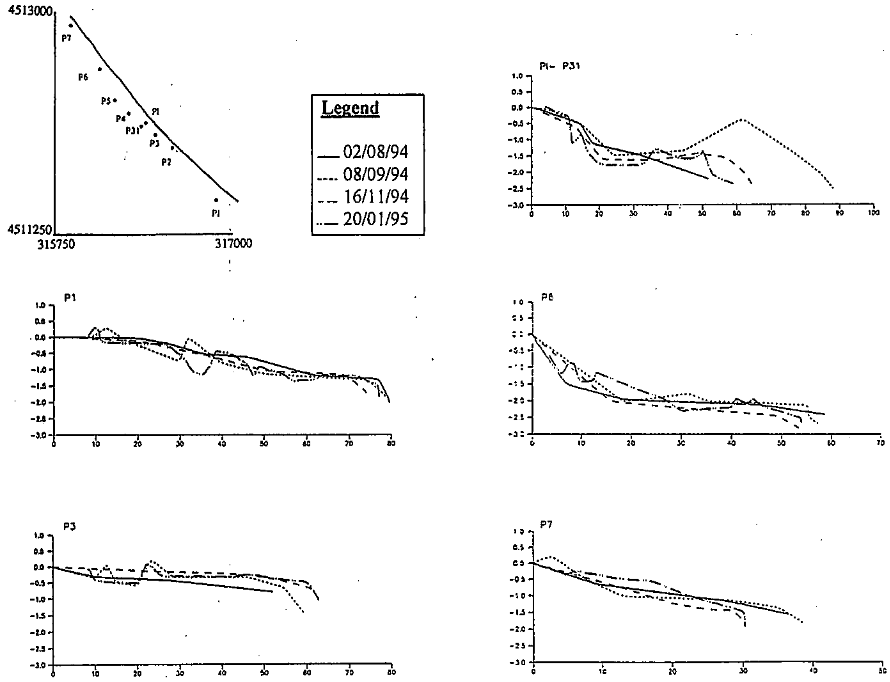

Fig. 3.- Emerged profiles at Ruimar zone during pilot experience in beach nourishment (in m)

Fig. 3.- Perfiles emergidos en la zona de Ruimar durante una experiéncia piloto de regeneración de playas (en m)

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